SOME NEW DIPLOGRAPTIDS FROM THE LLANDOVERY OF BRITAIN AND SCANDINAVIA

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ABSTRACT. *Pseudoclimacograptus hughesi* (Nicholson) and *P. undulatus* (Kurck) are placed in the new subgenus *P.* (*Metaclimacograptus*) with the former species as type. The following new subgenera and species are described: *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov. and *Glyptograptus* (*Pseudoglyptograptus*) *vas* subgen. et sp. nov.

JAANUSSON (1960, p. 326) drew attention to some of the differences between the Ordovician and Silurian representatives of the genus *Pseudoclimacograptus sensu* Přibyl 1947. Whilst our examination of *Climacograptus hughesi* (Nicholson) and *C. undulatus* Kurck (the latter = *internexus* Törnquist and *extremus* H. Lapworth) largely confirms Jaanusson's remarks (op. cit., p. 327) concerning the nature of the supragenicular wall and median septum, an additional important difference is the presence, in the Silurian species, of a hood composed of microfusellar tissue (fig. 3*e*, *sensu* Urbanek 1966). This grows from the geniculum of each thecal tube and tends to further restrict an already narrow aperture. It is considered that the characters distinguishing the younger from the older species of *Pseudoclimacograptus* are sufficient to warrant their separation as a subgenus. The subgenus *P.* (*Metaclimacograptus*) is defined below, with *C. hughesi* (Nicholson) as type species.

The identification of a genicular hood in late climacograptids affords a remarkable parallel with closely similar hoods described by Urbanek (1958) in what he considers to be late representatives of the genus *Monoclimacis* Frech. It is of interest also that the tendency of these late climacograptids to form structures simulative of thecal hooks takes place at the same horizons as the first developments of thecal hooks in monograptids. Whereas in *P.* (*Metaclimacograptus*) the 'hook' is formed by growth of a hood from the geniculum of the succeeding theca, in *P.* (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov. there is a certain amount of eversion of the aperture coupled with an indentation of the most distal part of the free ventral wall (text-fig. 5).

A similar feature is seen in Glyptograptus (*Pseudoglyptograptus*) *vas* subgen. et sp. nov. which closely resembles *G.* (*Glyptograptus*) in the nature of the geniculum, but which exhibits some eversion of the thecal aperture and has a pronounced indentation of the distal part of the free ventral wall (text-fig. 6).

The three new subgenera are late, and relatively short-lived modifications of the respective long-ranging genera.

G. (*Pseudoglyptograptus*) has only been recorded from the *magnus* Zone and is best regarded as a direct offshoot of *G.* (*Glyptograptus*) resulting from changes similar to those which led to the formation of *P.* (*Clinoclimacograptus*), namely the development of an everted apertural margin and a distal indentation of the supragenicular wall.

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SYSTEMATIC DESCRIPTION

Suborder DIPLOGRAPTINA Lapworth 1880 emend. Bulman 1963
Family DIPLOGRAPTIDAE Lapworth 1873
Genus PSEUDOCLIMACOGRAPTUS Přibyl 1947

Type species. Climacograptus Scharenbergi Lapworth 1876.

Amended diagnosis. Diplograptid with supragenicular walls which are usually distinctly convex, occasionally slightly convex, and rarely almost straight or concavo-convex. Median septum zigzag, angular or undulating in proximal region, sometimes becoming straighter distally. Apertural excavations short and deep, often introverted. A genicular hood present in some late representatives.

Remarks. We agree with Jaanusson in setting apart the Silurian representatives of the genus (the presence of a genicular hood is a newly recorded distinguishing feature). However, the genera exhibiting the characteristics described herein are possibly late derivatives of *Pseudoclimacograptus* and they do not in our view merit more than subgeneric distinction. Thus *C. hughesi* (Nicholson) and *C. undulatus* Kurck (= *C. extremus* H. Lapworth and *C. interuexus* Törnquist) are included in a new subgenus *P.* (*Metaclimacograptus*). Whilst the supragenicular wall of *P.* (*M.*) *hughesi* is almost straight (text-figs. 1*a–c*), that of *P.* (*M.*) *undulatus* is as convex as some Ordovician species included by Jaanusson in *Pseudoclimacograptus* s.s. (e.g. *P. a. angulatus*). The median septum of *P.* (*M.*) *undulatus* is angular, a feature noted by Jaanusson, but that of *P.* (*M.*) *hughesi* is more undulating. In *P.* (*Clinoclimacograptus*) *retroversus* the median septum is undulating in the proximal region, but distally can be almost straight. In this species the supragenicular wall retains proximally the pronounced convexity typical of *P.* (*Pseudoclimacograptus*), but the apertural margin is strongly everted, tending to become almost hook-like (text-fig. 5), and the distal extremity of the supragenicular wall is concave.

The distinctive features in the thecal morphology of these late pseudoclimacograptids appear to reflect a general tendency in graptoloids at this horizon to form thecal 'hooks', whether this is by growth of a genicular hood, or by pronounced eversion of the apertural margin. The growth of a hood does not necessitate any other structural alterations, and the basic pseudoclimacograptid pattern is broadly retained and easily recognizable. It is quite possible, therefore, that *P.* (*Metaclimacograptus*) evolved directly from *P.* (*Pseudoclimacograptus*). The angular or strongly undulating median septum may simply be a modification related to reduced size of the rhabdosome and closely packed, alternating thecae.

The second way in which a hook may be formed, namely by eversion of the aperture and indentation of the distal portion of the supragenicular wall, naturally involves more fundamental changes of thecal shape, and affinities with the type subgenus are less easily recognizable, and probably further removed, than in *P.* (*Metaclimacograptus*). It is reasonable, however, to retain all these forms under *Pseudoclimacograptus*, since they possess essentially convex supragenicular walls, a climacograptid geniculum, and a median septum which can be zigzag, angular, or undulating. The following classification is, therefore, proposed:

P. (*Pseudoclimacograptus*) Přibyl 1947, type species *C. Scharenbergi* Lapworth.
P. (*Metaclimacograptus*) subgen. nov., type species *Diplograpsus Hughesi* Nicholson.
P. (*Clinoclimacograptus*) subgen. nov., type species *P.* (*C.*) *retroversus* sp. nov.

It is worthy of note that in the late monoclimacids described by Urbanek (1958) the same two tendencies can be recognized. Thus for example *Monoclimacis micropoma* (Jaekel) shows both genicular hoods and eversion of the apertural margin (see Urbanek, 1958, fig. 67A). Eversion of the apertural margin can also be seen in some early Wenlock monoclimacids, though in these species it has not yet been established whether the genicular 'spine' is in fact a hood of microfusellar tissue.

Subgenus P. (PSEUDOCLIMACOGRAPTUS) Přibyl 1947

Type species. C. Scharenbergi Lapworth 1876.

Diagnosis. Climacograptids with convex supragenicular wall; apertural excavations short, deep, and introverted; median septum mostly zigzag.

Subgenus P. (METACLIMACOGRAPTUS) subgen. nov.

Type species Diplograpsus Hughesi Nicholson 1869.

Diagnosis. Climacograptids with gently convex or almost straight supragenicular walls; apertural excavations short, deep, introverted, and partly covered by a hood growing from the geniculum of the succeeding theca; median septum angular to undulating.

P. (*Metaclimacograptus*) *hughesi* (Nicholson)

Text-figs. 1*a–c*

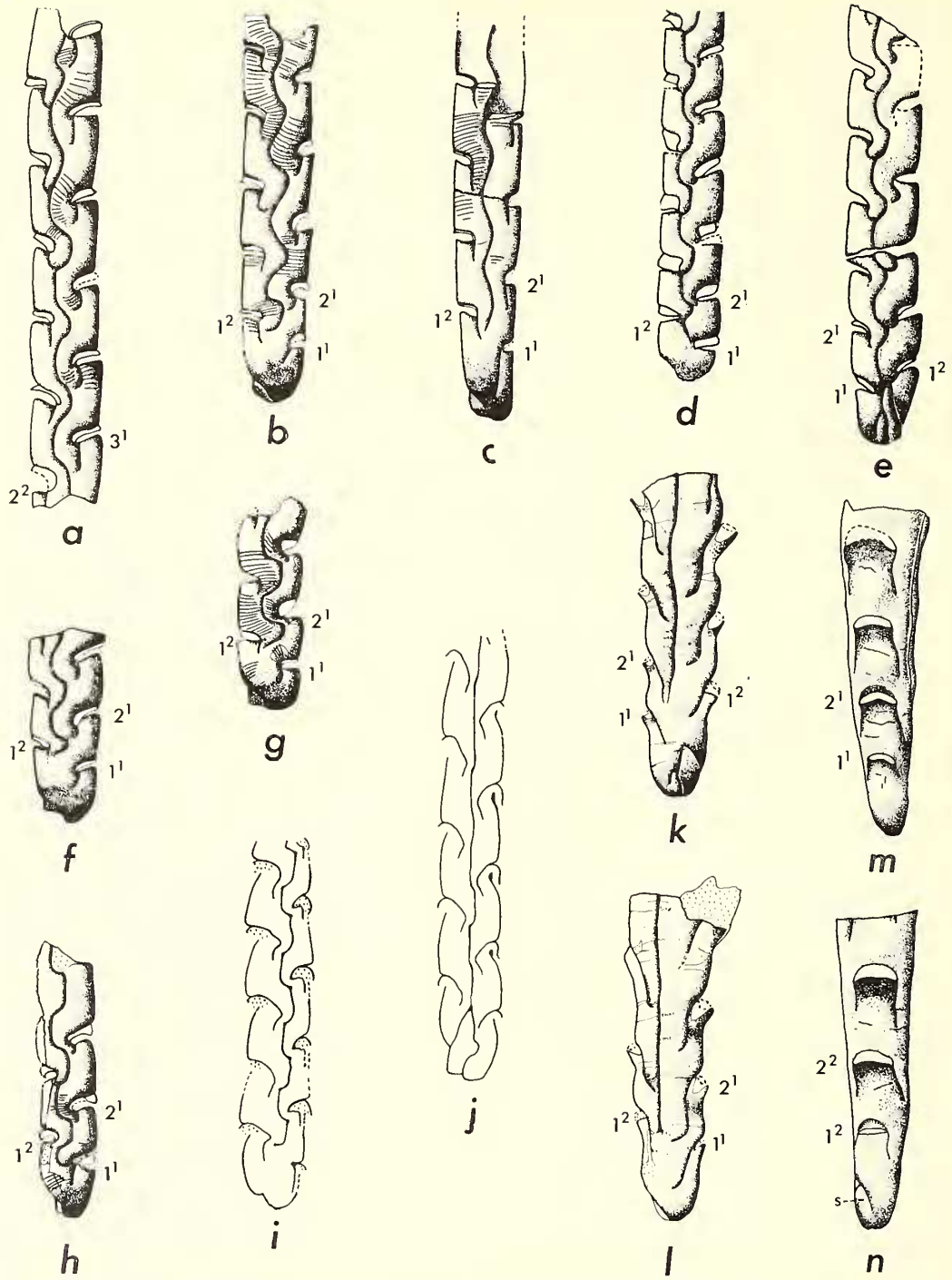
1869 *Diplograpsus Hughesi* (Nicholson), p. 235, pl. 11, figs. 9, 10.
1906 *Climacograptus Hughesi* (Nicholson); Elles and Wood, pp. 208–10, text-figs. 140*a–d*, pl. 27, figs. 11*a–e*.
? 1924 *Climacograptus hughesi* (Nicholson); Hundt, pl. 1, figs. 8–10.
? 1934 *Climacograptus hughesi* (Nicholson); Hsü, p. 67, pl. 5, figs. 7*a–c*.
? 1937 *Climacograptus hughesi* (Nicholson); Harris and Thomas, pp. 69–70, pl. 1, fig. 1.
1945 *Climacograptus hughesi* (Nicholson); Waterlot, pl. 8, fig. 130.
? 1947 *Climacograptus hughesi* (Nicholson); Ruedemann, p. 428, pl. 73, figs. 30, 31.
? 1965 *Climacograptus hughesi* (Nicholson, 1869); Stein, pp. 167–8 (pars), fig. 14*i*.

Neotype. The specimen figured by Elles and Wood 1906, pl. 27, fig. 11*a*. (Přibyl 1948). B.M. (N.H.) P1890.

Material. Several hundred specimens, mostly preserved in relief in pyrites, from England (Lake District, Cross Fell, Howgill Fells), Wales (Montgomeryshire, Cardiganshire), Scotland (Moffat), Ireland (Tyrone), Sweden (Tommarp), and Denmark (Bornholm).

Horizons. Llandovery Series Silurian, *acinaces-magnus* Zones of Wales, and equivalents.

Description. The tiny rhabdosome is circular in cross-section and parallel-sided after the first three or four thecae, reaching a maximum length of about 1 cm., and a width of less than 1 mm. Most specimens preserved in relief have a width of 0·5–0·6 mm. at the level of th 1^1 and quickly reach a maximum of 0·6–0·7 mm. A few specimens have been seen in which the maximum width is 0·8 mm. Flattened specimens are about 1 mm. wide.



TEXT-FIG. 1*a–c*. *Pseudoclimacograptus* (*Metaclimacograptus*) *lughesi* (Nicholson): *a*, S.M. A23911, specimen in relief from *acinaces* Zone, Rheidol Gorge; *b*, S.M. A23912, specimen in relief from

(The theoretical width, πr, of a flattened specimen is 0·95–1·10 mm.) The proximal end is rounded and the sicula visible in obverse view for up to 0·65 mm. The total length of the sicula can be estimated from flattened specimens (in which it can sometimes be detected 'pressed through') at approximately 1 mm. The visible part of th 1^1 grows downwards for 0·2–0·3 mm. before turning upwards for a distance 0·5–0·8 mm. Th 2^1 is the dicalycal theca.

The median septum is complete. On the obverse side it extends proximally as far as the exposed portion of the sicula, whilst on the reverse side the proximal extremity of the median septum is seen curving towards th 1^2 a short distance above the proximal extremity of the $1^2/2^2$ interthecal septum (text-figs. 1*b*, *c*). In the proximal part of the rhabdosome the median septum usually undulates rather more strongly than distally, and in some of the earlier specimens (e.g. text-figs.1*a*, *b*, of specimens from the *acinaces* Zone) there are traces of the angularity characteristic of the whole length of median septum in *P.* (*M.*) *undulatus* (Kurck) (described below). The later *hughesi* specimens, however, have a more gently undulating median septum (text-fig. 1*c*, a specimen from the *triangulatus* Zone).

The nema is only rarely prolonged beyond the distal end of the rhabdosome. Within the rhabdosome it is centrally positioned and is embedded in the median septum. In this position the median septum is straight for a short distance each side of the nema.

The thecal tubes are uniform, strongly sigmoidal, and have a short, deep excavation, whilst the supragenicular wall is almost straight, and the thecal aperture distinctly introverted. At the extreme proximal end the thecae tend to be more tightly packed and are commonly spaced as closely as 16 in 10 mm. The over-all thecal spacing is 16–12 in 10 mm. Each thecal tube exhibits a slight transverse narrowing visible in ventral view, as the aperture is approached. The thecal overlap is not more than one quarter.

A small number of specimens have been found in which a delicate genicular hood is still preserved (text-fig. 1*a*, *b*). The structure appears identical with that observed in *P.* (*M.*) *undulatus* (described below), where the hood can be shown to consist of microfusellar tissue with closely spaced growth bands and no visible zigzag suture. In both species the genicular hood is totally unconnected with the preceding thecal tube and should not be regarded as a dorsal extension of the latter. The effect of the genicular hood is to further restrict an already narrow and slit-like aperture. In general form the hood resembles the apertural lappets described in *Dicellograptus* sp. (James 1965), though of course the lappets are composed of normal fussellar tissue (compare for example text-fig. 3*e* herein with text-fig. 7 of James 1965). Like the lappets in *Dicello-*

acinaces Zone, Rheidol Gorge; *c*, S.M. A24965, specimen in relief from *triangulatus* Zone, Rheidol Gorge, listed Sudbury 1958, p. 487. *d–j. Pseudoclimacograptus* (*Metaclimacograptus*) *undulatus* (Kurck): *d*, S.M. A23090 specimen in relief from Upper Graptolite Shales, Tommarp, Sweden; *e*, *f*, respectively obverse and reverse views of S.M. A20218, specimen in moderate relief from Skelgill, Lake District; *g*, S.M. A23550, specimen in relief from *convolutus* Zone, listed Jones 1945, p. 320; *h*, S.M. A23561 specimen in relief, listed Jones 1945, p. 321; *i*, Lund, LO1111t, approximate longitudinal section prepared by Törnquist from pyritized specimen, originally figured by him 1893, fig. 27; *j*, Lund LO1110t, approximate longitudinal section of pyritized specimen prepared and figured by Törnquist 1893, fig. 26. *k–n. Glyptograptus* (*Pseudoglyptograptus*) *vas* subgen. et sp. nov., holotype, Geol. Surv. WEG 4058, *magnus* Zone, Cross Fell, specimen in full relief, apertures slightly damaged: *k*, obverse view; *l*, reverse view; *m*, apertural view of first series of thecae; *n*, apertural view of second series of thecae.

All figures ×15.

graptus sp., each genicular hood achieves its greatest development in the lateral, not the ventral, position (text-fig. 3*e*).

Remarks. The distinctions of *P.* (*M.*) *hughesi* from *P.* (*M.*) *undulatus* (Kurck) are dealt with under the description of the latter species. Elles and Wood (1906) included *Climacograptus undulatus* Kurck and *C. internexus* Törnquist in their synonymy of *C. hughesi* (Nicholson). However, examination of Törnquist's (1893) specimens of *internexus* (the 1890 specimens are lost) shows that it is conspecific with *C. extremus* H. Lapworth, whilst Törnquist himself later (1897) considered that his *internexus* was conspecific with, and junior to, *C. undulatus* Kurck.

P. (*Metaclimacograptus*) *undulatus* (Kurck)

Text-figs. 1*d–j*, 3*e*

? 1853 *Diplograpsus teretiusculus* (Hisinger); Richter, p. 456, pl. 12, figs. 11–13.
? 1871 *Diplograptus teretiusculus* (Hisinger); Richter, pl. 5, figs. 5–7.
1882 *Climacograptus undulatus* Kurck, p. 303, pl. 14, fig. 11.
1890 *Climacograptus internexus* Törnquist, p. 25, pl. 2, figs. 8, 9.
1893 *Climacograptus internexus* Törnquist; Törnquist, p. 6, figs. 23–27.
1897 *Climacograptus undulatus* Kurck; Törnquist, pp. 9–10, pl. 1, figs. 22–44.
1900 *Climacograptus extremus* H. Lapworth, pp. 134–5, figs. 22A–B.
1906 *Climatograptus extremus* H. Lapworth; Elles and Wood, pp. 210–11, text-figs. 141*a–c*, pl. 27, figs. 13*a–b*.
? 1947 *Climacograptus* cf. *extremus* H. Lapworth; Ruedemann, pp. 426–7, pl. 72, figs. 20, 21.

Holotype. Kurck's original figure (pl. 14, fig. 11) would seem to be a somewhat idealized drawing of a specimen upon what is known to be his type slab (LO479T). There are numerous specimens of *undulatus* on this slab but only one specimen is a reverse view with ten thecal pairs developed.

Horizon of Holotype. Cyphus Zone, Bollerup, Sweden.

Material. Many specimens in relief, infilled with pyrites, from England (the Lake District, Cross Fell, Howgill Fells), Wales (Montgomeryshire, Cardiganshire), and Sweden (Tommarp and Bollerup).

Horizons. Llandovery Series, *cyphus-sedgwickii* Zones, ? *turriculatus* Zone.

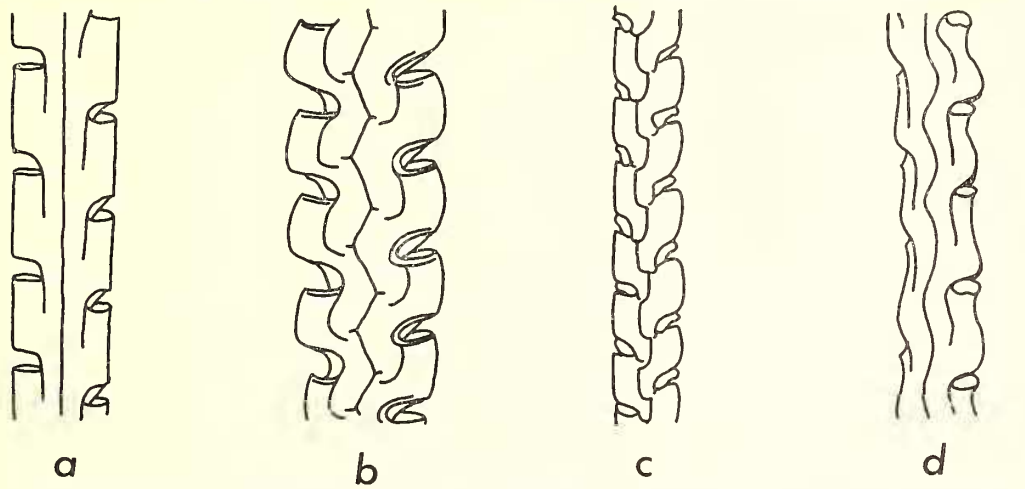
Description. P. (*M.*) *undulatus* is one of the smallest known climacograptids, having a length usually less than 7 mm. and a maximum width, in relief, of 0·5–0·6 mm. At the level of the th 1^1 the width is 0·4–0·5 mm. The rhabdosome is circular in cross-section. Both H. Lapworth (1900) and Elles and Wood (1906) considered the sicula to be completely enveloped by the early thecae, but it would seem that they were familiar only with the reverse aspect of the species, for in obverse view the sicula is visible for fully half a millimetre (text-fig. 1*e*). The total length of the sicula is unknown. The visible portion of th 1^1 grows downwards for a distance of approximately 0·3 mm. before turning upwards just below the level of the sicular aperture. The thecae are small, closely packed, and exhibit strong sigmoidal curvature with a typically climacograptid geniculum. The excavation is short and deep and the thecal apertures are introverted. Each thecal tube shows a slight transverse narrowing, visible in ventral view, as the aperture is approached (text-fig. 3*e*). The thecal overlap does not exceed $\frac{1}{5}$–$\frac{1}{6}$.

Well preserved specimens show the presence of a genicular hood. Text-fig. 3*e* illustrates a particularly good specimen in which the form of the hood can be seen. The hood which grows from the geniculum of th 8^2 (i.e. overhanging the aperture of th 7^2)

exhibits closely spaced growth-lines. These are much closer together than the growth-lines of normal fusellar tissue, and the hood is almost certainly composed of microfusellar tissue.

At the proximal end the thecae are slightly more closely spaced at about 18–20 in 10 mm. whilst the over-all thecal spacing is 15–20 in 10 mm.

The median septum is complete and angular throughout the length of the rhabdosome. On the obverse side of the rhabdosome it originates at the distal end of the exposed portion of the sicula (text-fig. 1*e*), whilst in reverse aspect it first appears slightly above the proximal



TEXT-FIG. 2. Diagrammatic comparison of some climacograptid thecal types: *a*, *Climacograptus* s.str.; *b*, *Pseudoclimacograptus* (*Pseudoclimacograptus*); *c*, *P.* (*Metaclimacograptus*) subgen. nov.; *d*, *P.* (*Clinoclimacograptus*) subgen. nov. Approximately ×15.

extremity of the $1^2/2^2$ interthecal septum (text-fig. 1*f*, *g*) and, as in *hughesi*, the 2^1 is the dicalycal theca. In one recorded instance (text-fig. 1*h*) it seems to originate closer to the first series of thecae at about the level of the aperture of th 1^1. Even in the absence of growth-line evidence it would seem that this specimen is abnormal and that th 1^2 must be the dicalycal theca.

The angularity of the median septum is quite unlike the zigzag septum of earlier pseudoclimacograptids. If the median septum is considered, for example, in relation to th 8^2 of text-fig. 3*e* it will be seen that the median septum is *concave towards* the early part of th 8^2 and *convex towards* the later part of th 8^2.

Remarks. It is possible that *P.* (*M.*) *undulatus* is a direct descendant of *P.* (*M.*) *hughesi*. An incipient angular median septum is detectable in some earlier (*acinaces* Zone) specimens of the latter species (text-figs. 1*a*, *b*). *P.* (*M.*) *undulatus* may have separated from *P.* (*M.*) *hughesi* at about this level, for the first specimens with a completely angular median septum are recorded at the base of the *triangulatus* Zone.

It may be possible to interpret the evolution of the median septum in terms of the general climacograptid evolution. Silurian climacograptids are mostly smaller and narrower than the Ordovician representatives of the genus, whilst the latest climacograptids in each group are very tiny (e.g. *P. undulatus*, *Climacograptus miserabilis*,

C. innotatus). The angular median septum exhibited by *P.* (*M.*) *undulatus* is more efficient in terms of close packing of tiny, alternating thecal tubes than either the undulating or zigzag types of earlier pseudoclimacograptids. *P.* (*M.*) *undulatus* is the smallest (and last) pseudoclimacograptid known at present. (The last of the climacograptids, an aseptate form as yet undescribed, is of similar dimensions to *P.* (*M.*) *undulatus* and occurs towards the top of the Llandovery Series in the Lake District.)

The main distinguishing features between *undulatus* and *hughesi* may be summarized as follows:

a. *undulatus* is shorter and narrower than *hughesi*;
b. the thecae are more closely spaced and have less overlap than in *hughesi*;
c. the supragenicular wall in *hughesi* is usually almost straight;
d. the median septum of *undulatus* is angular, not undulating.

Subgenus P. (CLINOCLIMACOGRAPTUS) subgen. nov.

Type species. *P.* (*C.*) *retroversus* sp. nov.

Diagnosis. Climacograptid with proximally convex and distally concave supragenicular walls; apertures strongly everted so that they face ventrally; median septum gently undulating in the proximal region, often almost straight distally.

P. (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov.

Text-figs. 3*a–c*, 4*a–c*, 5.

1893 *Climacograptus scalaris* (Hisinger); Törnquist, pp. 2–6, figs. 1–3, 5–8, 11–15, ? 4, 9, 10, 16–22.
non 1890 *Climacograptus scalaris* (Hisinger); Törnquist, p. 23, pl. 11, figs. 12–15.

Holotype. A specimen in the Elles collection (Sedgwick Museum, A52951), text-fig. 4*b*.

Horizon and locality of holotype. Upper Graptolite Shales, Tommarp, Sweden. The assemblage on the slab suggests *sedgwickii* Zone.

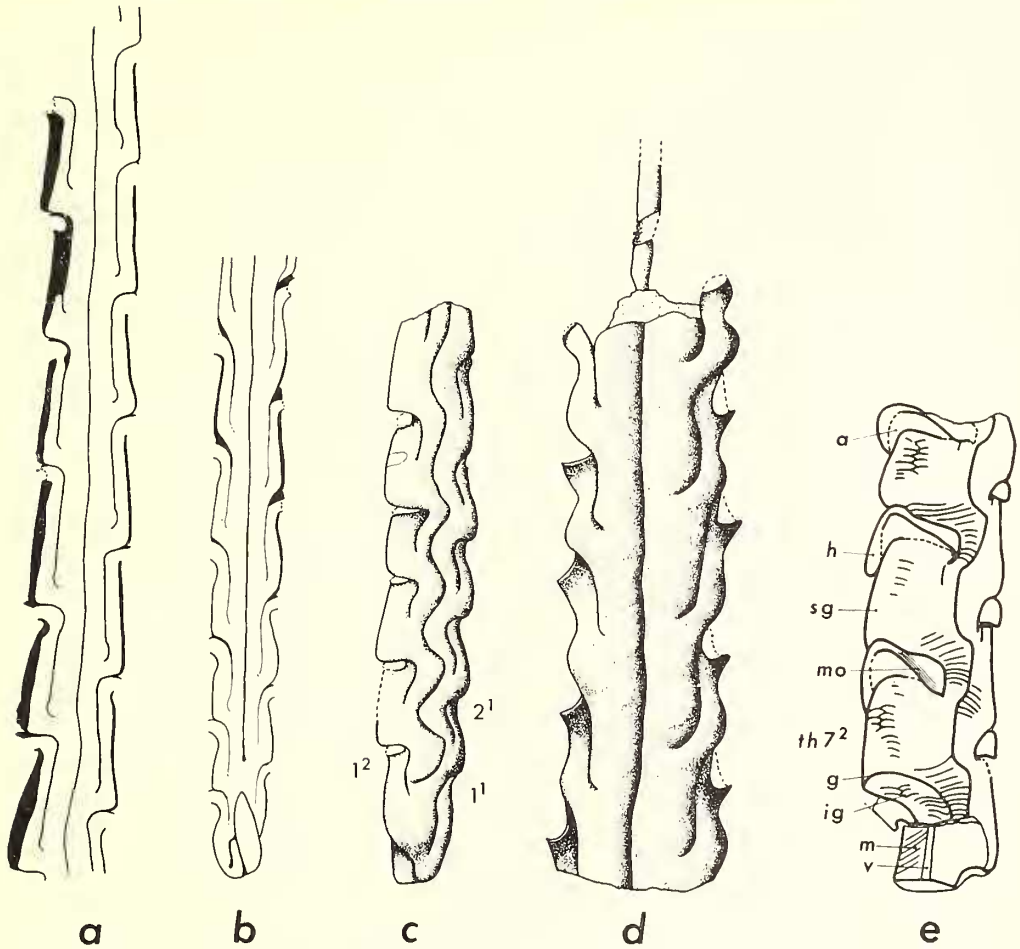
Material. Several hundred specimens in relief, flattened, or both (text-fig. 4*b*).

Derivation of name. Refers to the almost hook-like thecal apertures.

Horizons and localities. *Triangulatus* Zone, Rheidol Gorge (horizon F of Sudbury 1958); *magnus* Zone, Cross Fell; *convolutus* Zone, Cross Fell and Coalpit Bay, Ireland; *sedgwickii* Zone, Howgill Fells (Lake District) and Tommarp (Sweden).

Description. The rhabdosome is circular in cross section, up to 2·5 cm. in length and reaches a maximum width (in relief) of 1·0 mm. Some specimens exhibit a distal reduction in width, whilst the majority of specimens are about 0·8 mm. wide throughout most of their length. The proximal end is rounded and possesses a short virgella. In obverse aspect (text-fig. 4*c*) the sicula is visible for up to 0·8 mm. of its total length, which is approximately 1·3 mm. The sicula is visible in reverse view for about 0·3 mm. Th 1^1 is first seen 0·3 mm. above the sicular base and grows down to the level of the sicular aperture before turning upwards.

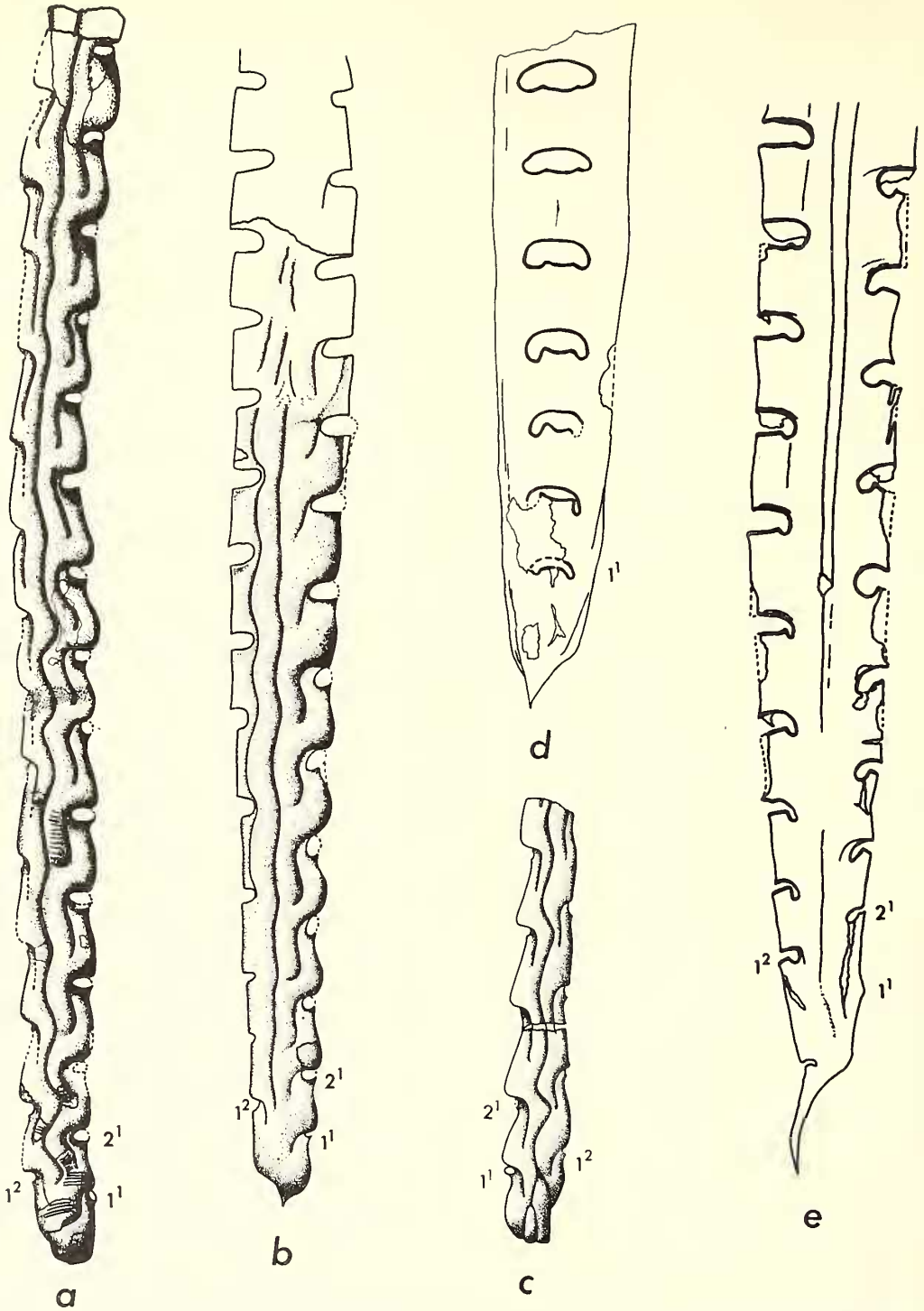
The median septum is complete. On the obverse side it extends proximally as far as the exposed portion of sicula (text-fig. 4*c*), whilst on the reverse side the proximal



TEXT-FIG. 3*a–c*. *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov. ×15: *a*, Lund LO1096t, approximate longitudinal section prepared and figured by Törnquist 1893, fig. 6; *b*, Lund LO1097t, longitudinal section close to nema prepared and figured by Törnquist 1893, figs. 7 and 8; *c*, S.M. A24939 internal mould somewhat compressed along its length, *triangulatus* Zone (horizon F), Rheidol Gorge, listed Sudbury 1958 as *Climacograptus lugluesi*. *d*. *Glyptograptus* (*Pseudoglyptograptus*) *vas* subgen. et sp. nov., distal end of holotype, Geol. Surv. no. WEG 4058, *magnus* Zone, Cross Fell. ×15. *e*. *Pseudoclimacograptus* (*Metaclimacograptus*) *undulatus* (Kurck), subapertural view of part of S.M. A52953, from Upper Graptolite Shales, Tommarp, Sweden; a, apertural region; h, hood; sg, supragenicular wall; mo, microfusellar tissue; g, geniculum; ig, infragenicular wall; m, median septum; v, virgula. ×30.

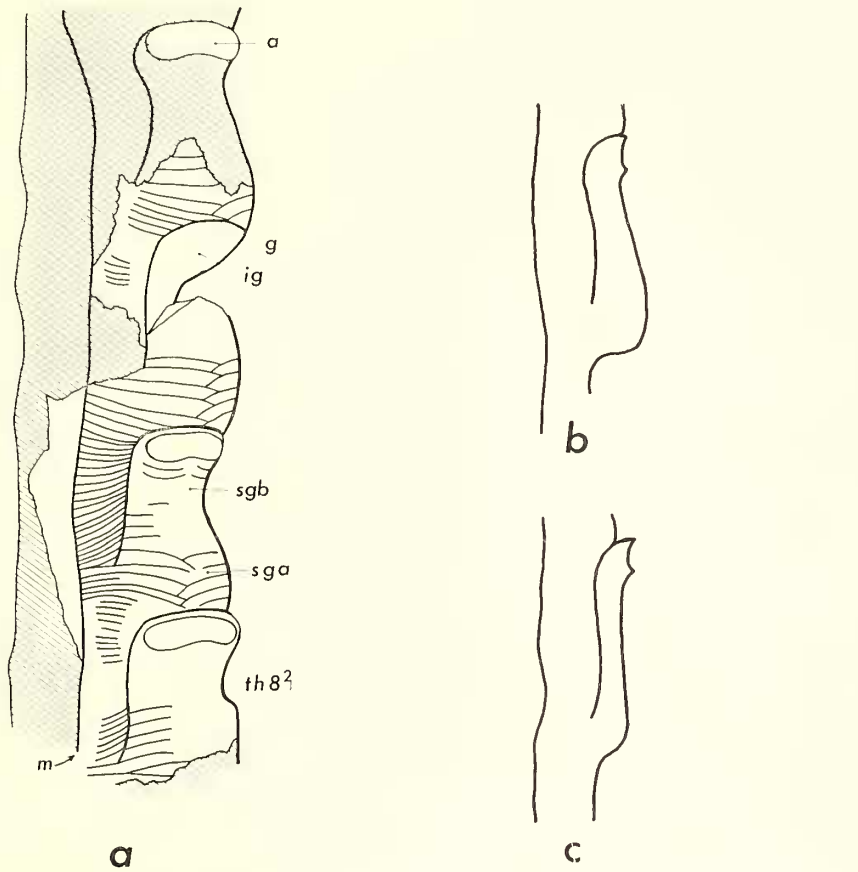
extremity curves towards the second thecal series just below the level of the aperture of th 1^2, but above the level of the proximal end of the $1^2/2^2$ interthecal septum (text-figs. 3*c*, 4*a*, *b*). It is probable, therefore, that th 2^1 is the dicalycal theca. The median septum is more or less straight distally, but in the proximal region varies from strongly to gently undulating (compare text-figs. 3*a* and *b*).

The thecae are uniform, strongly sigmoidal, and have a climacograptid geniculum. The supragenicular wall is at first convex and, as the thecal aperture is approached,



TEXT-FIG. 4*a–c*. *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov.: *a*, S.M. A23951 from *sedgwickii* Zone, Spengill, Westmorland, subapertural view; *b*, holotype, S.M. A52951, specimen preserved in relief proximally, and distally flattened, Elles Colln., Tommarp, Sweden, probably *sedgwickii* Zone; *c*, Geol. Surv. no. WEG 4052, *magnus* Zone, Cross Fell, specimen in full relief. *d–e*. *Climacograptus scalaris*, *sensu* Törnquist 1890. *d*, apertural view of flattened specimen on same slab as '*e*'; *e*, Lund, LO935t proximal end of flattened specimen originally figured by Törnquist 1890, pl. 2, fig. 12. All figures ×15.

becomes concave (text-fig. 5). The thecal apertures are strongly everted. Thecal overlap is about one-half. In the proximal region the thecae are more closely spaced (12–13 in 10 mm.) than distally, where they number 10 in 10 mm.

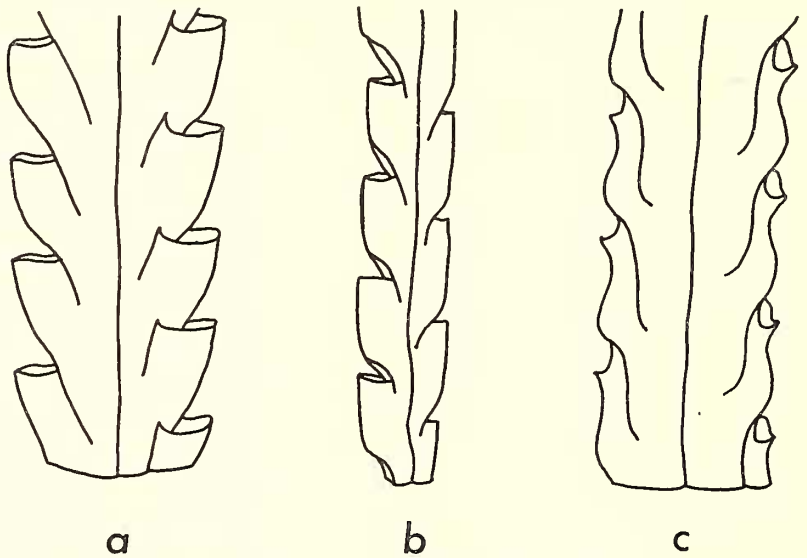


TEXT-FIG. 5. *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* subgen. et sp. nov., S.M. A52952, Elles Colln. *a*, subapertural view of part of specimen preserved in relief infilled with pyrites. Periderm (oblique ruling) has been removed to reveal growth-lines on the pyrite internal mould. Thecal aperture of th 10^2 has been removed to reveal infragenicular wall of th 11^2 (ig); m, median septum; sga, supragenicular wall, convex part; sgb, supragenicular wall, concave part; g, geniculum; a, thecal aperture. ×30; *b*, *c*, longitudinal sketch sections, respectively at the level of the zigzag suture and close to the lateral margin of the rhabdosome, to show the form of the 'hooks'.

Remarks. The above description deals with specimens preserved in relief, where thecal details can be ascertained with relative ease. A disconcerting feature of this species, however, is that upon flattening the peculiar and characteristic features (concavo-convex supragenicular wall, and ventrally facing apertures) become unrecognizable. The holotype (text-fig. 4*b*) is a specimen preserved in relief proximally and flattened distally. The distal end is quite indistinguishable from a flattened rhabdosome of an ordinary climacograptid, and were it not for these relatively rare specimens preserved both flattened and in relief, the flattened forms might easily be referred to '*Climacograptus*

scalaris' sensu lato. It will be noted also that the holotype is preserved as a subapertural view of the first thecal series: since the rhabdosome is almost circular in cross-section the preservation of a specimen flattened in true profile must be subject to a large element of chance. It is possible that a true-profile, flattened specimen might show the concavo-convex supragenicular wall.

Examination of Törnquist's (1893) specimens of *C. scalaris* shows them to be referable to *P.* (*C.*) *retroversus* and to be quite distinct from his 1890 specimens of *C. scalaris* (text-figs. 4*d*, *e* herein). These latter forms have an Ordovician aspect, and it is uncertain if these are conspecific with the true *C. scalaris* (Hisinger).



TEXT-FIG. 6. Diagrammatic comparison of *Glyptograptus* (*Pseudoglyptograptus*), *c*, with *G.* (*Glyptograptus*), *a* and *b*, approximately × 15.

P. (*C.*) *retroversus* is a common fossil in the *convolutus* and *sedgwickii* Zones, and it seems probable that some of the recordings of *C. scalaris* from these levels really indicate the presence of flattened specimens of *retroversus*. *C. scalaris* was regarded by Elles and Wood as a relatively uncommon species.

P. (*C.*) *retroversus* is a long-ranging species and it is possible when further material is available from the *triangulatus* and *magnus* Zones that the species may be subdivisible into several stratigraphically useful forms.

Genus GLYPTOGRAPTUS Lapworth 1873

Type species. *Diplograpsus tamariscus* Nicholson 1868.

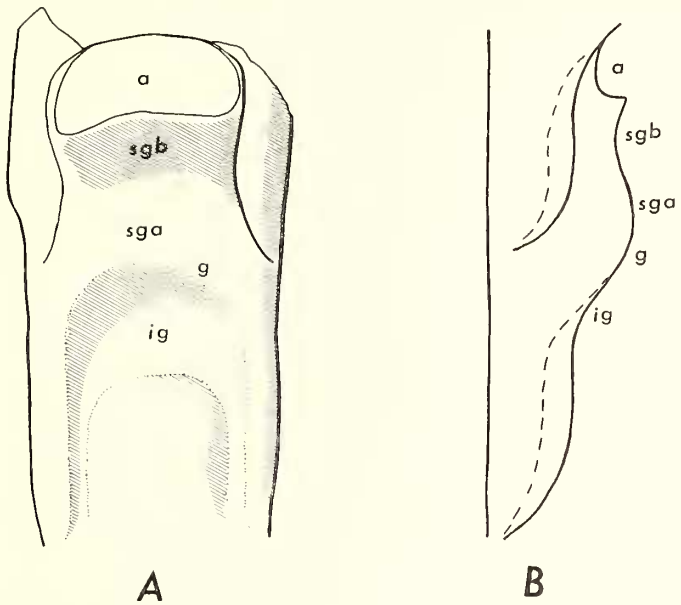
Amended diagnosis. Thecae with gentle sigmoidal curvature; supragenicular wall almost straight, sloping outwards, or rarely with gentle double (concavo-convex) curvature; apertural margins horizontal, undulate, or rarely everted; rhabdosome cross-section ovoid or nearly circular.

Remarks. The generic diagnosis is amended to include the form *Glyptograptus* (*Pseudoglyptograptus*) *vas* subgen. et sp. nov.

Subgenus G. (GLYPTOGRAPTUS) Lapworth 1873

Type species. Diplograpsus tamariscus Nicholson 1868.

Diagnosis. Thecae with gently sigmoidal curvature, apertural margins commonly undulate; cross-section ovoid or nearly circular.



TEXT-FIG. 7A, B. Apertural and lateral views of a manually isolated thecal tube of *Glyptograptus* (*Pseudoglyptograptus*) *vas* subgen. et sp. nov., partially diagrammatic, S.M. A52958. a, thecal aperture; sga, supragenicular wall, convex portion; sgb, supragenicular wall, concave portion; g, geniculum; ig, infragenicular wall; dashed lines indicate course of thecal tube in the prothecal groove, full explanation in text. ×30.

Subgenus G. (PSEUDOGLYPTOGRAPTUS) subgen. nov.

Type species. G. (*P.*) *vas* sp. nov.

Diagnosis. A glyptograptid distinguished by its concavo-convex supragenicular wall, strongly everted aperture, and a sub-apertural, transverse constriction.

G. (*Pseudoglyptograptus*) *vas* sp. nov.

Text-figs. 1*k–n*, 3*d*, 7*a*, *b*

Holotype. WEG4058, a specimen preserved in the Geological Survey Museum (Leeds), fig. 1*k–u*, 3*d*.

Horizon of holotype. Magnus Zone, Llandovery Series.

Derivation of name. (L.) *vas*, vase-shaped, referring to the ventral thecal aspect.

Horizon and localities. Magnus Zone, Howgill Fells and Cross Fell.

Material. Four well-preserved specimens in full relief (WEG4058; A52956–8); and other fragmentary or poorly preserved specimens.

Description. The maximum observed rhabdosome length is 3·5 cm., which includes a distally projecting nema of at least 1 cm. The rhabdosome has a circular cross-section. At a distance of 5 mm. from the rounded proximal end the rhabdosome attains a width of 1·0 mm. and thereafter widens steadily to 1·8 mm. at 2·5 cm. The thecae number 11–12 in 10 mm. at the proximal end, and about 9–10 in 10 mm. distally. In the obverse view of the holotype (text-fig. 1*k*) the sicula is visible for 0·6 mm. of its total length, which is unknown. The visible part of the 1^1 grows down from 0·3 mm. to the level of the sicular aperture (text-fig. 1*k*) before turning upwards.

The proximal extremity of the median septum, in obverse view (text-fig. 1*k*), extends close to the $2^1/3^1$ interthecal septum. In reverse aspect it reaches to just below the level of the 1^2 thecal aperture (text-fig. 1*l*). This suggests that th 2^1 is the dicalycal theca: th 2^2 and 3^1 appear to originate almost simultaneously from th 2^1. There is no growth-line evidence available. The median septum is almost straight.

The thecae are strongly sigmoidal, with a glyptograptid genicular angle. In apertural view the width of the metathecal portion is somewhat narrower than the rhabdosome width (text-fig. 7A), whilst the whole metatheca fits into a pronounced hollow in the succeeding protheca (text-fig. 7A, B). The thecal tubes, therefore, have a somewhat greater volume than is apparent in lateral view. The supragenicular wall is convex immediately above the geniculum, but as the apertural lip is approached becomes strongly concave. Moreover, immediately below the thecal aperture the metathecal tube exhibits a pronounced transverse narrowing, so that the thecal tube in ventral view has a vasiform appearance (text-fig. 7A). The aperture is strongly everted.

Remarks. A comparison of text-figs. 5 and 7 emphasizes that a similar stage has been reached in both late pseudoclimacograptids and late glyptograptids. The pseudoclimacograptid lacks the flowing geniculum and ventral, prothecal groove of *G.* (*P.*) *vas.*

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